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Boosting math skills: The impact of game-based instruction on problem-solving in students with learning disabilities

تعزيز مهارات الرياضيات: تأثير التعليم القائم على الألعاب على حل المشكلات لدى الطلاب ذوي صعوبات التعلم

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Abstract

This study investigated the effect of game-based instruction on the learning of mathematical concepts and problem-solving skills in students with learning disabilities. The participants were 60 fourth-grade students identified with mathematical disabilities, divided into experimental (n=30) and control (n=30) groups. A semi-experimental pretest-posttest design with a control group was used. The experimental group received a 25-session intervention using game-based instruction. The results, analyzed using the paired-samples t-test, showed that the experimental group obtained significantly higher scores in the learning of mathematical concepts and problem-solving skills compared to the control group. This suggests that game-based instruction is an effective strategy for improving mathematical learning outcomes in students with learning disa-bilities.

Keywords: game –based instruction, learning math concept, problem-solving, students with learning disa-bilities.

الملخص

بحثت هذه الدراسة في تأثير التعليم القائم على الألعاب على تعلم المفاهيم الرياضية ومهارات حل المشكلات لدى الطلاب ذوي صعوبات التعلم. شارك في الدراسة 60 طالبًا من الصف الرابع الابتدائي ممن يعانون من صعوبات في الرياضيات، وقُسِّموا إلى مجموعتين تجريبية (العدد= 30 طالبًا) وضابطة (العدد=30 طالبًا). استُخدم تصميم شبه تجريبي ذي القياس القبلي والبعدي مع مجموعة ضابطة. تلقت المجموعة التجريبية تدخلًا تعليميًا قائمًا على الألعاب لمدة 25 جلسة. أظهرت النتائج، التي حُلِّلت باستخدام اختبار "ت" للعينات المقترنة، أن المجموعة التجريبية حققت درجات أعلى بكثير في تعلم المفاهيم الرياضية ومهارات حل المشكلات مقارنةً بالمجموعة الضابطة. وهذا يشير إلى أن التعليم القائم على الألعاب يُعد استراتيجية فعالة لتحسين نتائج تعلم الرياضيات لدى الطلاب ذوي صعوبات التعلم.

الكلمات المفتاحية: التعليم القائم على الألعاب، تعلم مفاهيم الرياضيات، حل المشكلات، الطلاب ذوو صعوبات التعلم

Introduction

Learning disabilities (LDs) are considered to be a general term for a series of heterogeneous cognitive dysfunctions. LDs are manifested in obvious difficulties in learning skills such as reading, mathematics, and writing. Individuals with learning disabilities have normal intelligence, but there is a large gap between their actual academic performance and the performance that can be achieved with their intellectual potential (Eissa & Mostafa, 2013; Elhoweris, 2017; Hoogendoorn, 2021; Ahmed Nassar, 2019). LDs usually include developmental learning disabilities and academic learning disabilities. The former include attention deficits, perceptual deficits, visual-motor coordination deficits, and memory deficits. The latter include reading disabilities, writing disabilities, and mathematics disabilities (Filiz & Güneş, 2022; Gomaa, 2016). LDs not only affect an individual's academic performance, but also have many negative effects on the individual's emotions, social interactions, and life in adulthood (Melekoglu et al., 2023; Zaien, 2021).

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Learning disability is a confusing condition because each person has a unique set of talents and characteristics. Students with learning disabilities are not blind, but they cannot see many things like their peers; they are not deaf, but in many cases they cannot hear or hear sounds like normal people. They are not cognitively delayed, but they learn in a different way (Gomaa, 2016).

Mathematics is one of the most complex human systems and one of the basic tools for learning (ElAdl, 2020; Koç & Korkmaz, 2020). Learning mathematics helps to enhance logical thinking and is also the foundation on which other areas of knowledge rely. However, the failure rate of mathematics learning is the highest, especially in the last stage of basic education (Koç & Korkmaz, 2020). In the process of learning mathematics, some students think that mathematics is a complex subject, so they lack interest in learning mathematics and suffer from poor mathematics performance. However, there are also some students who have normal intelligence but encounter more difficulties in the field of mathematics learning than other students. These students are children with mathematics learning disability (MLD) (Fatahalla, 2024)

Mathematics learning disability (MLD) is also called mathematical disability (MD), dyscalculia and developmental dyscalculia (Ikhwanudin & Suryadi, 2018). MLD refers to the phenomenon that students' mathematical learning performance lags behind that of children of the same age or grade due to the lack of ability or skills related to mathematical learning (Fatahalla, 2024). Before the 1970s, the research on learning disabilities (LD) mainly focused on dyslexia. It was not until the 1970s that mathematical disabilities received attention and concern

Therefore, mathematics is considered one of the basic sciences, and lack of interest in this subject leads to learning disabilities. Ultimately, it not only causes academic failure and waste of funds, but also leads to students' criticism and humiliation, the formation of a weak self-concept and a decrease in their self-esteem, and it also endangers their mental health. And it may lead them to unsuccessful defense mechanisms. These problems are carried from school and students to home and family, spreading anxiety and dissatisfaction in all areas of life, and the result of all this is severe damage to the mental health of society.

One of the methods used to expand and improve educational situations is the use of educational games (Aydın et al., 2024). The type of game is selected according to the needs of the students. It provides them with the opportunity to learn and practice these patterns through play (Sánchez Castillo et al., 2016). Playing strengthens students' social relationships, participation, trust, and a spirit of cooperation, development of learning processes such as observation, experiential learning, problem solving, and creativity in students, and most importantly, it makes learning enjoyable for students (Yang et al., 2021).

There are studies concerning game –based instruction in improving students' mathematics learning that have confirmed the effectiveness of this method (Debrenti, 2024). For example, results of Setyaningrum et al. (2018) indicated that the students who were exposed to the game-based learning within problem solving approach significantly outperformed their counterparts who were exposed on the basis of textbook within problem solving. Cayang & Ursabia (2024) affirmed that implementing game-based learning strategies in mathematics instruction is highly effective, resulting in a notable enhancement of learners' academic performance compared to conventional teaching methods. Additionally, the study of Munda et al. (2024) found statistically significant differences in the pre-test and post-test performances of their student subjects after applying the educational games.

The present study

The ability to count, understand unit by unit quantities, sort, subtract and compare numbers all depend on the experiences of objects. A child who has limited accuracy, insufficient perception and poor motor development may not have the desired experiences in activities related to manipulating and handling objects. Therefore, he will not be ready to achieve a real understanding of spatial relationships, shape, order, time, dimension and quantity. Game –based instruction can improve learning math concept and problem-solving in students with learning disabilities. There is a lack of experimental research to explore whether game –based instruction can improve learning math concept and problem-solving in students with learning disabilities.

Gaps and research Aims

Based on the lack of experimental research to explore whether game –based instruction and its effect on improving learning math concept and problem-solving in students with learning disabilities, this study clarifies the effect of game –based instruction learning math concept and problem-solving in students with learning disabilities, and summarizes the corresponding educational intervention strategies on this basis, in order to provide certain guidance and direction for front-line education and teaching work and future research.

Main hypothesis: Effect of training

As for our main hypothesis, it is predicted that students with learning disabilities who were trained in game –based instruction would increase earning math concept and problem-solving in posttest. Statistical analyses to test this hypothesis have been conducted with parametric tests.

Methodology

Research Design

A semi-experimental design with a pretest and posttest design with a control group was utilized by creating a game-based strategy (see figure 1).

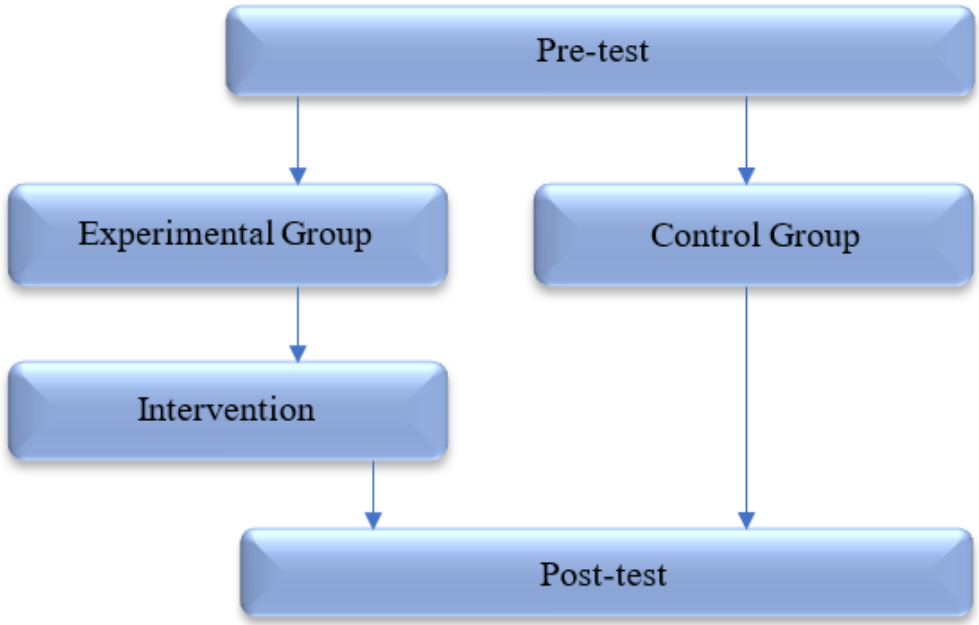

Figure 1. Research design.
(by the author)

Sample and Sampling Method

Children in the 4th grade from three primary schools in Taif city were selected to participate in the selection phase. With the help of schools Math teachers, Mathematics Academic Achievement Test was administered to the target students. The test scores were converted into standard Z scores according to grade, using performance below the 25th percentile (Andrade, 2021) as the cutoff score, selecting those whose with performance below the 25th percentile of the grade (standard score of 40 or scaled score of 5). Children were categorized as having mathematics learning disabilities if their performance on a standardized mathematics achievement test was below the 16th percentile (IQ < 80) or if their mathematical achievement was 1.5 standard deviations below their IQ score. Among the students, 60 were identified as children with math disabilities. The average age of the students upon entry to the study in the 4th grade was 9.94 years (SD = 0.88). To prevent the experimental results being affected by different instructors, the selected classes were taught by the same instructor. Parents were informed of the method of instruction that was used in the

treatment group of participating classrooms, but were blind to their student's placement in a treatment or control classroom. Randomization is the process of assigning participants to treatment and control groups (Peat, 2011), assuming that each participant has an equal chance of being assigned to any group, ensuring no a priori knowledge of group assignment (ie, allocation concealment). The sample was divided into two groups: experimental (n=30 students) and control (n=30 students)

Data collection

Mathematics concepts Test: This test was developed particularly for this study. It contains 15 questions under 3 dimensions: Geometry and Measuring (5 questions), Concept of Multiplication (5 questions), and Fractions (5 questions). In order to determine the reliability of the tests, 40 fourth grade elementary school students answered them at one-week intervals. The correlation coefficient between the scores obtained from the two equivalent tests was 0.79. Therefore, the **mathematics concepts test** has relatively good validity and reliability.

Mathematics Problem Solving Test: This test was developed particularly for this study. It contains 15 questions under 3 dimensions: Math Word Problems (5 questions), Addition and Subtraction Problems (5 questions), and Problem-solving Questions (5 questions). Time Sampling (Test-retest reliability). To determine whether the results of the test were stable over time, a study was completed in which raters completed the inventory twice, 3 weeks apart. The resulting coefficient was .89

Statistical Analysis

A Paired T-test was used to determine if there was a significant difference between math concept and problem-solving before and after utilizing the game-based strategy in terms of learners' scores.

Ethical Considerations

Gathered data were utilized to fulfill the study's purpose only. As such, the students' participated in the study voluntarily, and their agreement was sought through an informed consent form. All the data gathered were treated just for research purposes only and students were in complete anonymity.

Description of the educational training program

First session: Students got to know each other, formed groups of three, encouraged their cooperation in group activities, explained the duties of each member and each group, explained how to play the game and the purpose of playing the games in question. Second, third and fourth sessions: The selected activity of the second session was the game "Find and Write". In this game, each group was given a basket with several balls on which a mathematical exercise (single-digit addition or subtraction) was written. One of the group members picked up a ball and then, with cooperation and common thinking, they solved the exercise on it in the activity notebook. In the third session, two-digit addition or subtraction was done, and in the fourth session, three-digit addition and subtraction.

Fifth, sixth and seventh sessions: In the fifth session, the game "Accuracy" was selected as an activity. In this game, students used cubes with different numbers written on them to arrange the addition or subtraction (single-digit) expressions with the answer, and one of the group members wrote it in the activity notebook.

In the sixth session, the exercise (two-digit) was written on the board and the group members arranged the cubes according to it. In the seventh session (advanced stage), each student did one- or two-digit exercises individually. Eighth, ninth, and tenth sessions: The optional activity of the eighth session was the "number pantomime" game. In this game, one of the students showed one-digit, two-digit, or three-digit numbers with the help of the fingers of both hands, and the other students stated the desired number and wrote it on the sheet. In the ninth session, one of the mathematical functions (addition or subtraction) was shown in the form of a pantomime. The students consulted with each other in the group and answered in cooperation. In the tenth session (the advanced stage of this activity), the exercise was done individually.

The eleventh, twelfth, and thirteenth sessions: In the eleventh session, the goal was to learn problem-solving skills, and the optional activity for this session was "role-playing," which was performed through a play. In

this game, a group consulted together and performed a play related to daily shopping that represented a mathematical problem, such as: buying several types of stationery that required adding up their prices.

Other students in the group consulted with each other and answered the problem first orally and then on paper. At first, the price of stationery and other items was a single digit, but in the next session, two-digit and three-digit numbers were considered. This activity was also answered individually in the thirteenth session. The fourteenth, fifteenth, and sixteenth sessions: The goal was to examine and strengthen visual abilities. The desired activity was "pattern finding," which was performed in groups according to the color of the layers. In the fifteenth session, pattern-finding was done based on geometric shapes and in the sixteenth session, based on numbers.

The seventeenth, eighteenth, and nineteenth sessions: The goal was to strengthen auditory memory and the activity was "Let's be together." In the seventeenth session, each student was given a number. The students had to come to the front of the class according to the addition or subtraction (single digit) written on the board and their number. The student who had the number corresponding to the answer solved the exercise with the help of friends. In the eighteenth session, the same activity was done, but with two-digit addition and subtraction and group consultation. In the nineteenth session, both types of exercises were written individually.

The twentieth, twenty-first, and twenty-second sessions: Increasing problem-solving skills. The goal of these sessions and the related game was "Magic Ball." Accordingly, before the session, the addition or subtraction (single digit) was written on the balls in the basket. One person from each group took a ball from the basket, then with the help of friends, they told a short story. In the twenty-first session, the same procedure was followed, but with the solution written in the activity notebook. In the twenty-second session, addition and subtraction with two-digit numbers were done.

In the twenty-third, twenty-fourth, and twenty-fifth sessions: In order to increase the accuracy and concentration of the students, the game "Matching Familiar Shapes" was considered. In this game, several cards with a number of shapes related to different shapes (such as leaves, trees, and animals) that had slight differences from each other were provided to the groups. Group members had to choose a shape from the given shapes. The next session was the “Maze-Finding” game. Two similar pictures with a few minor differences were provided to the groups so that they could find the differences with each other. In the next session, a picture containing a number of hidden animal pictures was provided to the students. The students first had to find the hidden pictures accurately, then color them.

Results and discussion

To test hypotheses, mean and standard deviation of Mathematics concepts Test and Mathematics Problem Solving Test scores in the pre- and post-tests for each group. As shown in Table 1, differences existed between the mean scores of the experimental and control groups in the pre-test and post-test. Children in experimental group had higher scores in all Mathematics concepts Test subscales than did those in the control group, and in Mathematics Problem Solving Test, children in experimental group had higher scores in all subscales than did those in the control group (See table 1).

After that, the covariance analysis test was used to determine how significant were the differences, as shown in Table 2. After controlling for the pre-test effect, there was a significant difference between the pre-test and post-test scores of children in the experimental group in the subscales of executive functions and theory of mind (ToM) skills ($P \leq 0.05$).

Table 1.
Mean and standard deviation of Mathematics concepts Test and Mathematics Problem Solving Test scores in the pre- and post-tests for each group

Variables	Mean ± SD
Mathematics concepts Test	
Geometry and Measuring	
Experimental	
Pretest	2.15 ± 0.863
Posttest	4.66 ± 0.272
Control	
Pretest	2.17 ± 1.001
Posttest	2.23 ± 1.144
Concept of Multiplication	
Experimental	
Pretest	2.11 ± 0.663
Posttest	4.48 ± 0.411
Control	
Pretest	2.15 ± 0.842
Posttest	2.19 ± 2.115
Fractions	
Experimental	
Pretest	2.18± 0.449
Posttest	4.62 ± 0.623
Control	
Pretest	2.16± 0.744
Posttest	2.35± 0.981
Mathematics Problem Solving Test	
Math Word Problems	
Experimental	
Pretest	2.15 ± 1.221
Posttest	4.56 ± 0.446
Control	
Pretest	2.20 ± 1.310
Posttest	2.21± 0.865
Addition and Subtraction Problems	
Experimental	
Pretest	2.10 ± 1.000
Posttest	4.70 ± 0.433
Control	
Pretest	2.12 ± 1.001
Posttest	2.19± 0.681
Problem-solving Questions	
Experimental	
Pretest	2.17 ± 1.116
Posttest	4.88 ± 0.835
Control	
Pretest	2.16 ± 0.879
Posttest	2.18± 0.736

(By the author)

Table 2.
Covariance Analysis test Results for Comparing theory of mind (ToM) skills of Children in the Control and Experimental Groups

Source of Change	Sum of the Squares	Df	Mean Squares	F	P-Values	Effect Size
Mathematics concepts Test						
Pretest	2.20	1	2.20	12.4	0.001	0.39
Group	4.67	1	4.67	68.3	0.001	0.88
Mathematics Problem Solving Test						
Pretest	2.17	1	2.17	10.7	0.001	0.40
Group	4.69	1	4.69	69.4	0.001	0.89

Note.: ETA Square ranged from 0.45 to 0.87 for all variables respectively. High size effect (Cohen, 1988 suggested that =0.2 be considered a 'small' effect size, 0.5 represents a 'medium' effect size and 0.8 a 'large' effect size).
(By the author)

Discussion

The results of the present study showed that the experimental group that underwent the experimental game –based intervention obtained higher scores in learning mathematical concepts and problem-solving ability compared to the control group. In this study, the first hypothesis was that game –based instruction is effective in promoting students' learning of mathematical concepts. The results of the experiment and data analysis showed that this hypothesis was supported and game –based instruction improved students' learning of mathematical concepts, and the mean scores of the variable learning of mathematical concepts of the experimental group subjects in the post-test situation increased significantly compared to the control group. Therefore, it can be said that game –based instruction was effective in improving students' learning of mathematical concepts.

Game-based Learning and Mathematics

These results are supported by other studies in the literature. For example, a study by Lin et al. (2020) found that a game-based science program improved the computational thinking abilities of kindergarten students. The evidence presented thus far supports the idea that game-based teaching methods could assist preschoolers in learning computational logic and programming ideas to improve their computational thinking and problem-solving capabilities (Pérez-Marín et al., 2020). A study by Xu et al. (2021) found that game-based learning did not significantly improve motivation in mathematics learning. Game-based learning using different game application tools emphasizes the importance of strengthening the foundation of math concepts and the mathematical proficiency to solve various problems in math. According to Orbon & Sapin (2022), using game-based learning in teaching influences the development of students' positive attitudes toward mathematics as the most challenging subject and boosts their motivation, accelerated acquisition, and longterm memory.

Thus, by playing games, discipline and accuracy in paying attention to the surroundings, discipline and accuracy in listening, discipline and accuracy in seeing, in speech and behavior, responsibilities, decision-making, discipline and accuracy in the ability to solve everyday problems are strengthened. In addition, he believes that the result of intellectual and physical preparation and activities carried out by students is solving problems and achieving peace and mental balance, all of which It produces effects and results that will lay the groundwork and determine how students will deal with problems, their attitudes, activities, and decisions in the future.

Children who are unable to learn mathematics have a delayed or interrupted development of normal attention and precision. Children with learning disabilities in mathematics, although they know mathematical operations well, make mistakes due to insufficient attention. Some believe that teachers should establish direct personal relationships with their students and consider their needs, abilities, and talents in arranging learning activities (Pérez-Marín et al., 2020). Above all, learning should be satisfying and self-directed. Students can use all their learning capacities when they enter the learning environment with interest and enthusiasm and love learning.

These results indicate that game –based intervention is an approach in which the teacher selects a specific tool according to the type of child's problem (Yeratziotis et al., 2024). The type of game is selected according to the needs of the students and, with his active participation while playing, he considers the new patterns needed by the students and provides them with the opportunity to learn and practice these patterns through the game (Adipat et al., 2021). In games, students' social relationships, participation, trust, and a spirit of cooperation are strengthened. Games promote the development of learning processes such as observation, experiential learning, problem solving, and creativity in students. It reinforces and, most importantly, makes learning enjoyable for students (Alotaibi, 2024).

Educational implications

Children must master a series of skills to learn mathematical tasks. The acquisition of these skills is through experience, training, and learning. Most children perform these skills automatically, but children with learning disabilities in mathematics have difficulty learning these skills and need to be given special training. Children gain their experiences in various ways, including games, during their growth period. Therefore, if teachers take steps to enrich the educational environment and design purposeful games, they will be effective to some extent in the development and improvement of children's learning. By using

purposeful, diverse, and attractive games in line with the goals of the mathematics lesson, in addition to making students with learning disabilities interested, learning mathematical concepts and problem-solving skills can also be improved so that they can use their knowledge in daily life and have sufficient accuracy and concentration in carrying out life's tasks.

Limitations

This study had limitations. Among them, it can be noted that the sample group was limited to the city of Taif and the research population, which was limited to boys. Therefore, it is better to proceed with caution when generalizing the results of this study to other geographical areas. It is also suggested that other researchers, using more efficient human resources and appropriate material resources, consider a larger statistical population and select the sample group from both female and male students. They can also examine the effect of other variables such as reading and painting on learning mathematical concepts and problem solving.

Conclusion

Learning mathematics is a social process, through which students build their mathematical knowledge and skills by collaborating with each other and in groups, and learning opportunities arise through group discussion, explanation, justification, and discussion about meaning and concept (Erath, 2021). Research has shown that children with learning disabilities are weaker than normal children in learning mathematical concepts (Landerl et al., 2009). The use of purposeful games to improve the cognitive skills of individuals with learning disabilities arises from the advancement of knowledge in the field of plasticity and self-healing capacity of the human brain, which has strong evidence that neuropsychological functions such as attention and concentration can be improved with the help of cognitive training (O'Connell et al., 2007; Zhong (2019) and by increasing the accuracy and concentration of students, the learning rate of mathematical concepts and problem-solving ability can also be improved.

Practical implications

Game-based learning transforms the educational paradigm from a teacher centered approach to one where learners actively participate in teamwork to grasp new concepts. Implementing game-based learning strategies in mathematics instruction is highly effective, resulting in a notable enhancement of learners' academic performance.

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